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Climate change adaptation through agroforestry: The case of Kassena Nankana West District, Ghana

Isaac Apuri, Kenneth Peprah*, Godwin Thomas Wedam Achana

University for Development Studies, Faculty of Integrated Development Studies, Wa Campus, P. O. Box 520, Wa, Upper West Region, Ghana

A B S T R A C T

The paper aims at assessing agroforestry as an adaptation strategy to a changing local climate. Agroforestry is necessitated by the need to improve tree population along the Sisili River and other areas in the Kassena Nankana West District. Primary data were generated through survey methods in which questionnaires were administered to 75 agroforestry farmers. It was triangulated with eight focus group discussions and five key informant interviews. Additionally, secondary data on rainfall and temperature (1984–2015) were analysed. The study revealed that farmers have noticed changes in the local climate as declining rainfall and increasing sunshine associated with rising temperature. Secondly, agroforestry was found to be useful in reducing water and wind erosion of soil, it improves soil nutrients, moisture retention and household food availability. Agroforestry is challenged with water shortages, unsupervised livestock grazing and bushfires. The study concludes that agroforestry is a dynamic agricultural adaptation option to a changing local climate. Therefore, the Ministry of Food and Agriculture and NGOs should support farmers with dams and fencing materials and encourage more farmers to adopt agroforestry.

1. Introduction

Many farmers in the developing countries produce food by using farm practices which are close to organic operations (Tal, 2018). They have developed their farming systems through many years of trial and error methods under variable climatic factors (Benneh, 1990). Farm sizes are smaller, normally, between 1.6 ha to 2.4 ha (Faulkner et al., 2008; Annor et al., 2009). Smallholder farmers are generally poor; they constitute about 85% of the world's farmers; they are commonly found in Africa; and, Ghana is no exception (IFAD, 2007; Tal, 2018). Farmers have observed changes in rainfall and temperature which they associate with variability in the climate. The farmers' perception is based on the fact that elsewhere, rainfall trend is ascending over the past three decades. Other regions portray descending rainfall trend over the same period. Whilst, temperature trend in all the regions shows increase for the past 30 years (Peprah, 2014; Peprah and N-yelkabong, 2017). This understanding is supported by impacts of occurrence of extreme weather events. The earliest data indicate 1748 drought in the Gold Coast and the subsequent famine and loss of lives in 1749 (Doormont, 2016). In Ghana, there were droughts in 1961, 1971 and 1977 (Masih et al., 2014). The most devastating of all the droughts occurred in 1981–1983. The associated nationwide bushfires destroyed standing crops and farm produce (Ofori-Sarpong, 1986). The water level in the Volta Lake reduced drastically. Hence, electricity production by Akosombo Hydroelectric Dam and Kpong Hydro Station became unreliable. This situation recurred in 2005 and 2006 as well as 2013–2014. The effects of water level reduction in the Volta Lake became more serious resulting in national outcry in 2014–2016 over national over reliance on hydro-electric power generation which appears to be no longer supported by the weather and climate. Following these drought periods were

unexpected occurrence of extreme rainfall in 2007, 2010 and 2015 resulting in flooding of farmlands and cities. In 2007 some 30,000 houses collapsed due to flooding, and 200,000 metric tons of food crops destroyed. In 2015, floods directly kill 25 persons and indirectly caused the death of 200 people. They were trapped at the petrol/gas re-fill station where they sought for shelter from the rainfall. A twin disaster of flood and fire explosion at the site claimed their lives. Another impact is sea level rise at the coast necessitating the on-going construction of sea defence wall at Keta in the Volta Region of Ghana.

The discourse on the variability in the climate has been reinforced by some international assessments which confirmed variable rainfall and temperature occurrence in the country (USAID, 2011). "The country is projected to face rising temperatures, erratic rainfall and more extreme weather events. These climate change conditions are expected to expose the country to natural hazards such as flood and drought" (UNDP, 2018). Another report labelled Ghana as the eighth climate change vulnerable country in Africa (Kreft et al., 2014). A research found that Ghana contributes about 12.2 $MtCO_2e$ direct greenhouse gas emission at the year 2000 levels (Asante and Amuakwa-Mensah, 2015). The country is a signatory to the United Nations Framework Convention on Climate Change (UNFCCC). The Government of Ghana has prioritized six key areas in climate change policy. The policy seeks to address climate resilience in agriculture and food security, built infrastructure, communities and climate-related risks, increase carbon sinks, management of water and land ecosystems as well as access to water and sanitation. In support, UNDP-Ghana has established climate change data hub, an online one-stop information portal for Ghana's climate reporting (UNDP, 2018). The significance of this paper is the contribution it seeks to make to climate-smart agriculture. Previous studies have proposed agroforestry as climate change mitigation (IUCN, 2004; Zomer et al., 2008). However, the literature shows its increasing use as climate change adaptation (McCabe, 2013). Others consider agroforestry as both, climate change mitigation and adaptation (Verchot et al., 2007; Woodfine, 2009; Mbow et al., 2014b).

This study investigates the use of agroforestry by farmers as an adaptation strategy to variability in the local climate. Specifically, the study seeks to:

- examine farmers' perception on the changes in climate;
- investigate the various practices involved in agroforestry;
- analyse farmers' perspective on agroforestry as an adaptation to climate change; and,
- assess various challenges in agroforestry.

The paper is divided into five sections. The introduction shows Ghana's experience in a variable climate. It is followed by literature review on climate variability, adaptation and the linkages with agroforestry. Under methodology, study area and methods are described. Then, results and discussion are presented. Finally, conclusions and recommendations are drawn.

2. Literature review

The main focus of the Intergovernmental Panel on Climate Change (IPCC) is the change in mean and/or the variability shown in climate statistics. Normally, 30 years' data on climate of a place is used. However, 10 years' data can be used following the advice by the World Meteorological Organization (WMO) (Arguez and Vose, 2011). The IPCC attributes the cause of the changes to human activities and this is supported by 97% of climatologists (IPCC, 2014). The United Nations Framework Convention on Climate Change (UNFCCC) attributes the causes of the changing climate to both human and natural activities (UNFCCC, 2014). For example, modulations of the solar cycles and volcanic eruptions are natural activities, whilst land use activities are anthropogenic factors (IPCC, 2014). Evidence gathered by climate scientists established the fact that global climate is indeed changing with discernible consequences on life supporting systems including agriculture (IPCC, 2007; Verchot et al., 2007; Sivakumar, 2005). Considerable changes have been noticed in precipitation, temperature, sea level rise, frequency and intensity of extreme events in Africa. Other impacts include floods and drought (Badege et al., 2013; Verchot et al., 2007). It has been noted that the consequences of climate change on agricultural sector are enormous, posing serious challenges to development efforts in general and poverty reduction in particular (Mawere et al., 2013).

Adaptation is required for people to make adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts (IPCC, 2001). To achieve this objective, human systems should concentrate efforts on moderation of harm and/or exploitation of benefits (UNISDR, 2009). Adaptation could be private (done by individuals) or public (carried out by government) (Mendelsohn and Dinar, 1999). In the short term, adaptive strategies are used; while, adaptive processes belong to the long term. When the outcome is negative, mal-adaptation is the term but when adaptation is abandoned, no adaptation is used (Batterbury and Forsyth, 1999). Adaptation can be anticipatory (takes place before impacts start), autonomous (spontaneous strategies that happen to stem impacts earlier than later) or planned (policy actions to halt impacts) (UK Climate Impacts Programme, 2010).

Agroforestry refers to integration of trees, animals and crops on the same piece of farm land with economic and ecological interaction (Agidie et al., 2013; Woodfine, 2009). Farmers prefer the use of fruit trees to timber species due to the former's ability to generate income and produce supplementary food (Mbow et al., 2014a; Khan and Khisa, 2000). Agroforestry begins with raising seedlings in polythene bags (pots), preparing a seed bed, preparing the site, staking, collecting debris, digging deep pits, digging narrow ditches for watering, sowing or planting, collecting cow dung as fertilizer, making protective gabion, grafting particular plants, watering, weeding and mulching (Khan and Khisa, 2000:5). Agroforestry management practices involve tree pruning, crop diversification and rotation, mulching, application of farm manure and fertilization (Mbow et al., 2014a; Nair, 1993). Incentives of agroforestry include provision of largest carbon sink, wood energy, soil fertility and local or micro climate enhancement, reduction in

soil erosion, improvement in soil Nitrogen and soil organic matter, provision of ecosystem services and reduction of dependence on natural forest. Other benefits include income from the sale of tree products such as fuel wood, timber, honey, fruits and even herbs as well as soil nutrient retention (Rao et al., 2007; Thorlakson and Neufeldt, 2012; Nair and Garrity, 2012; Mbow et al., 2014a; Carsan et al., 2014).

The conceptual framework is informed by the relationship between climate change impacts and adaptation strategies (Ozor et al., 2012). When as a result of climate change weeds, pests and disease increase, farmers adapt with the use of cover cropping, increased weed removal and mixed cropping. In the case of reduction in moisture or drought, they use mulching, irrigation scheme and drought resistant crops. Reduction in soil nutrients is stemmed by applying composting, mixed cropping, crop rotation and fallowing. Decrease in agricultural yields is remedied by application of chemical fertilizer or manure as well as improved seed varieties. Also, vegetation loss and land degradation are solved with agroforestry practices, reducing tillage and afforestation.

3. Methodology

The study area focuses on Kassena Nakana West District (KNWD) of the Upper East Region of Ghana. It was created in 2007 by Legislative Instrument (L. I. 1855) and took effect from 29th February 2008. The KNWD shares boundaries with Burkina Faso to the north, Bongo District to the north-east, Bolgatanga Municipal to the east, Kassena Nakana Municipal to south, Bulsa District to the south-west and Sissala East District to the west. It is located on latitudes 10°57′32″ and 10.95889° North of the equator and longitudes 01°06′48″ and 1.11333° West of the Greenwich Meridian. The climate is the tropical continental or interior savanna type with rainfall values between 1000 and 1150 mm. Rainfall occurs from May to October with relative humidity between 70% and 90%. The hottest month is March with average temperature of 36 °C and coolest is April with 27 °C. Soil erosion is low in the rainy season because the relief is undulating rising to 300 m above sea level with few isolated hills like Fie (9280 m), Zambao (360 m) and Busono (350 m). The dry season begins from late November to early March with relative humidity of 20%. During this period, the District comes under the North East Trade Winds locally called harmattan. This air mass comes with winter cold from continental Europe. As it passes through the Sahara Desert, it becomes warm, dry and dusty. The vegetation is the Guinea savanna characterized with tussock grasses of different heights, fire resistant and deciduous tree. Trees commonly found in the District are Dawadawa (*Parkia biglobosa*), Shea (*Vitellaria paradoxa*), Baobab (*Andansonia digitata*), Neem (*Azadirachta indica*) and Mango (*Magirifera indica*). During the dry season the grasses dry up and become highly inflammable. River Sissili is the main river in the KNWD. It is a tributary of the White Volta River. There are isolated ponds and dug-outs which collect and store run-off water for use in the dry season. The soil type is Savanna Ochrosols. The KNWD has a population of 70,667 with 50.8% males and 49.2% females. The population density is 81 persons per square kilometer. Agriculture is the main livelihood option and it employs 90.7% with 98.2% concentrating on crop farming. They engage in supplementary livelihood activities such as livestock farming (78%), tree planting (0.9%) and fishing (0.1%).

Four communities were purposefully selected based on their significant progress in agroforestry farming. They included Nakrong, Kajelo, Sakaa and Nakolo (Fig. 1).

These communities were selected based on a number of indicators such as the visible presence of trees; integration of crops among
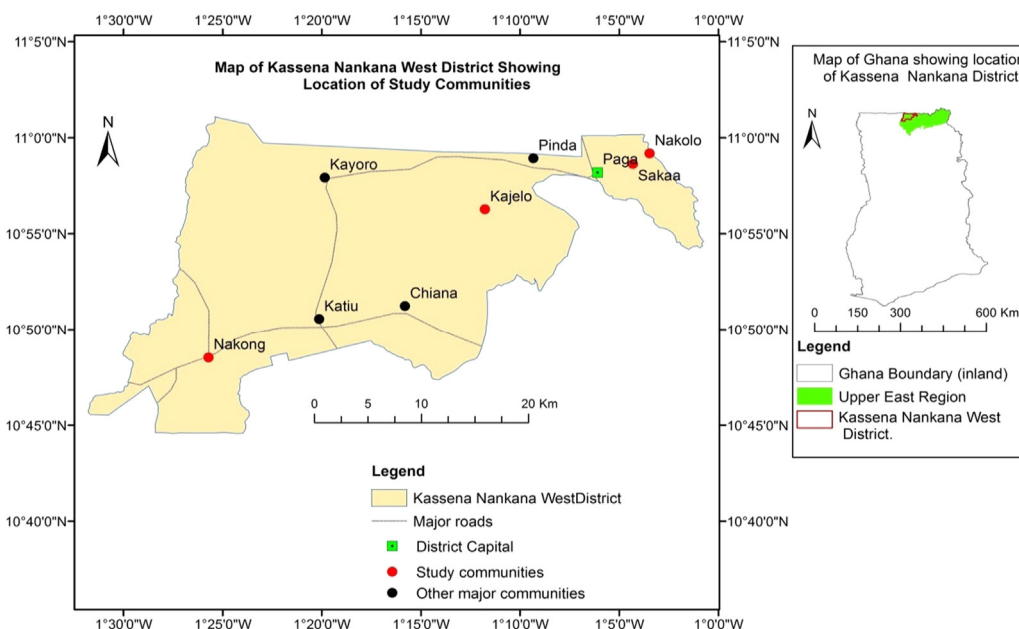
Fig. 1. Map of the Study Area.
Source: Adapted from Ghana population census (GSS, 2014)

Table 1
Summary of Methods of Study.

Research methods	Specific to this study
Research Design	Case Study Approach
Research Methods	A mix qualitative and quantitative methods
Qualitative Methods (Primary Data)	In-depth information from Agroforestry farmers, extension officers
Quantitative Data (Secondary Data)	Rainfall and Temperature data from Ghana Meteorological Agency (GMet)
Study Population	Owner of agroforestry farm (75 farmers), agroforestry promoters (5)
Sample size (75 farmers) distribution	Nakong = 16
	Nakolo = 23
	Sakaa = 19
	Kajelo = 17
Sampling (Purposive)	Snowball sampling (1st respondent located in the farm)
Data collection techniques	Questionnaire – semi-structured (75), key informant interview using a guide (5) and focus group discussions (8) two per the four communities – gender-based
Data Analysis	Use of Statistical Package for Social Sciences (SPSS) Descriptive statistics/frequencies and Recommended charts in Ms Excel

the standing trees; and the presence of agroforestry farmer association

A case study approach that permits the use of multiple methods was adopted. The data was collected from both primary and secondary data types from the field survey and relevant state institutions. Table 1 shows the research methods. Secondary data were sourced from Ghana Meteorological Agency (GMet) on rainfall and temperature for the period of 1984–2015.

The target research population was agroforestry farmers. Hence, they were the main source for primary data generation. Such data were generated by using the survey method and focus group discussion. A questionnaire was administered to a sample size of 75 agroforestry farmers. The major themes of the semi-structure questionnaire were farmers' perception of a changing climate, agroforestry practices, climate resilient agricultural adaptations and the challenges farmers face in agroforestry farming.

Eight (8) focus group discussions were organized for male and female groups in four (4) communities. This was done to create enabling condition for the women to speak freely. In the presence of their male counterparts, particularly, husbands the women are demanded by custom to keep quiet and allow the males to speak on their behalf. By customary practice, one needs the permission of the husband to speak to the wife. This practice is very common in northern Ghana. Hence, researchers often organize focus group discussion on gender basis. The groups enumerated and discussed general agricultural adaptations to the variable climate. Perspective of each group was sought on agroforestry as climate resilient adaptation.

For the purposes of triangulation, five key informants were interviewed. They include:

- two (2) District Agricultural Extension Officers,
- the Kassena Nankana District Development Planning Officer,
- the Manager of Ghana Meteorological Agency at Navrongo and,
- Programmes Coordinator of ORGIIS-GHANA (an NGO).

The analysis was based on descriptive statistics using frequency of occurrence and percentages. Direct quotations were used in the case of the key informant interview and focus group discussion.

4. Results and discussion

4.1. Examination of farmers' perception on a changing climate

Farmers' perception on a changing local climate is based on rainfall and temperature trends (Table 2). Majority of the agroforestry farmers (88%) claim rainfall is decreasing; some 9% rather has observed increasing rainfall and 3% has seen no change in rainfall (n = 75). The focus group discussion at Nakong shed more light on the majority view of reducing rainfall.

Table 2
Farmers' perceived effects of changes in the local climate.

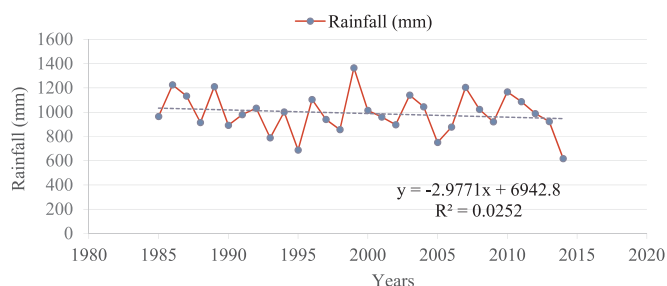| Variables	Freq.	%	Ranking of severity of impact (%)				
			1. not severe	2. moderately severe	3. severe	4. very severe	5. extremely severe
wind storms	75	100	0	1	15	30	54
Drought	74	98	0	4	19	29	48
Loss of soil fertility	62	83	0	8	28	48	16
erratic rainfall	49	65	0	15	10	30	45
incidence of pest and diseases	25	34	0	2	52	20	4
Floods	22	30	9	36	32	9	14

Fig. 2. Rainfall Trend for three decades Kassena Nankana West District.
Source: Ghana Meteorological Service, Navrongo, 2015

"In recent times, the rainy season starts late and ends earlier than expected. It usually ends before our crops mature. Also, the frequency of rainfall has reduced. The intervals between the rainfall days are becoming longer periods. This affects seeds germination and crop growth. Due to inadequate rainfall, water bodies are drying up and communities that are fortunate to have some water in their dams normally chase people from other communities away and prevent animals from drinking their water"

The general view was that rainfall has being decreasing. This study validates the farmers' claim with 30 years rainfall data depicted in Fig. 2. There is annual variability shown by the ups and downs in the 30 years rainfall curve. The linear trend line equation shows the decreasing rainfall as:

$$y = -2.977x + 6942.8 \quad R^2 = 0.0252$$

Rainfall in the study district follows what appears to be happening elsewhere in Ghana's savanna region in terms of decreasing rainfall. This finding agrees with analysis of rainfall data from 1961 to 2011 for Wa synoptic weather station in the Upper West Region which also indicates a decline in annual rainfall trend (Peprah and N-yelkabong, 2017).

$$y = -0.8685x + 1067$$

To the farmers, the beginning of rainfall is of considerable importance. It indicates the start of growing of crops. The very first rainfall in the year (onset of rainfall for that year) may start in April or May but growing of crops may not begin immediately. Sometimes the onset of rainfall is followed by dry spell in which period planted and germinated crops wither and die due to wilting point. The cessation of rainfall implies the length of the rainy season. It determines the crops which could be grown and the subsequent yield. The implication is that farmers who get the start right would end up with good yield while, the others may not. The cessation of rainfall showed only two months (October reported by 97% [73 of 75] and November, reported by 3%). The study found that rainfall begins in June and ends in October as observed by majority of agroforestry farmers (59%, n = 75). Hence, this finding agrees with that of Mensah et al. (2016). The authors found the onset of rainfall in the entire northern savanna to be in April and May. Cessation of rainfall was found to be in October. The end of the rainy season agrees with that of agroforestry farmers.

As regards temperature, the study shows 81% for increasing temperature, 15% for decreasing temperature and 4% for no change in temperature. Both maximum and minimum temperature from weather station records show increasing temperature as indicated in Figs. 3 and 4. A further validation of the farmers' claim on rising temperature levels. The increasing temperature depicted is supported by literature. Temperature in Upper West Region is increasing between 1.1 °C and 1.6 °C (Rademacher-Schulz and Mahama, 2012). If the current situation does not improve, there is a prediction that rising temperature in Upper West Region will reach 2 °C–4.2 °C in the near-future (2045–2065) and in the far-future (2081–2100) (Techie-Obeng et al., 2010). Generally, temperature in the Upper East Region is higher than that of Upper West Region. The literature shows day time temperature in Upper East Region as 40 °C and night time temperature as 19 °C (Callo-Concha et al., 2013).
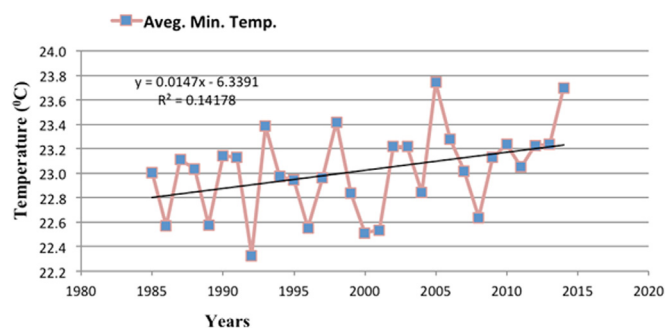

Fig. 3. Trend in Average Minimum temperature (°C) from 1985 to 2014.
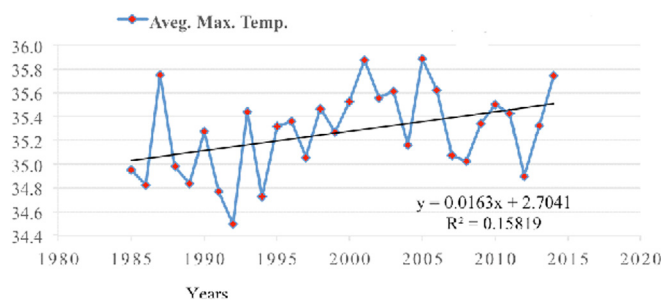**Source: Ghana Meteorological Service-Navrongo, 2015**

Fig. 4. Trend in Average Maximum temperature (°C) 1984–2014.
Source: Ghana Meteorological Agency-Navrongo, 2015

With respect to wind storms, farmers were quick to point to the destruction often caused by strong winds to farms and property. About 88% mentioned breaking of trees and crops; affect fruiting process negatively (41%), cause soil erosion (35%) and affect crop yield (23%). The winds disaster is reported by a farmer at Nakolo as:

"In the past, we use the direction of the wind to predict when it will rain, now we can't do that because the wind blows anyhow. Wind storms have become so severe; they uproot trees and blow away top particles of the soil".

The key informant at the Navrongo weather station intimated that wind storms recorded in the district often reach 51–70 knots.

"We have experienced very strong and destructive storms in the past. Often, crops, trees and buildings are destroyed".

A farmer at Kajelo intimated:

"I cannot tell what is happening to the weather conditions in recent times, there are changes in the weather patterns, it does not rain at the time we want the rains. The warm season is becoming longer than it used to be and one cannot determine the direction of the wind"

The agroforestry farmers agree that there are two different wind storms (Padi, 2017). One originates from the east of Ghana and brings the onset of rainfall with 700 hPa to 200 hPa (haP refers to hecto-pascal; height level equivalence of air pressure) which reaches about 30 knots. This wind is stronger than the second wind storm which originates from the west of Ghana. The second wind storm brings harmattan with a level of 200 hPa. The key informant assertion of the first wind storm of 51–70 knots is a local situation which requires further verification.

At the farm level, farmers consider the following as anthropogenic causes of the variability in their local climate: tree felling (39 of 75, 52%), charcoal production and bush burning (26 of 75, 35%) as well as the use of tractor for ploughing farms (8 of 75, 11%). Whereas 15 farmers (20%, n = 75) do not know the causes, 16 farmers (21%, n = 75) attribute the cause to God (nature). Consequently, the effects of the changes in the local climate are reported by 75 farmers (100%) as wind storm, 74 farmers (98%) as drought, 62 farmers (83%) as loss of soil fertility, 49 farmers (65%) as erratic rainfall, 25 farmers (34%) as incidence of pests and diseases as well as 22 farmers (30%) as floods (Table 2).

4.2. Practices involved in agroforestry

Table 3 displays the trees used in agroforestry farming. The crops include maize (76%), groundnuts (55%), rice (52%), millet (41%), beans (28%) and vegetables (25%). Farmers keep livestock such as goat (40%), cattle (27%), sheep (25%), pigs (7%) and donkeys (1%). Table 4 shows importance of the trees. For example, whitehorn tree (*Acacia albida*) shed leaves in the rainy season to

Table 3
Trees used by farmers in agroforestry practices.

Local name	English name	Planted or natural	Botanical name
Kanzono	whitethorn	Natural	*Acacia albida*
Sogo	shea	Both	*Vitellaria paradoxa*
Mangwo	mango	Planted	*Mangifera indica*
Atea	cashew	Planted	*Anacadium occidentale*
Tio	baobab	Natural	*Adansonia digitata*
Feilatio	neem	Both	*Azadiracta indica*
Sugu	dawadawa	Both	*Parkia clapatoniana*
	eucalyptus	Planted	*Ecucalyptus camaldulensis*
	cacia	Planted	*Cassia semea*
	Albesia	Planted	*Albezia lebbeck*
Tiki	teak	Planted	*Tectona grandis*
pino	Mahogany	Both	*Khaya senegalensis*
Gungu	kapok	natural	*Ceiba pentandra*

Table 4
Importance of the agroforestry trees.

Trees	Socioeconomic importance	Ecological/production importance
Whitethorn	Source of fuel wood	Shed its during raining season to fertilize the soil
	Thorny parts makes it a good fencing material for planted trees	Absence of shade during farming season
	Bark and roots are medicinal	
	The fruits are sold to generate income	Increase soil fertility drastically
		Fruits and leaves are good source of fodder
		Animal droppings around it
Shea	Sale of nuts for Income	Leaves add to soil nutrients
	Constructional material	Improve vegetation cover
	Fencing material	
	Source of material for carving mortar and farm implements	Moderate microclimate
	Extract butter for household use	
Dawadawa	Prepare dawadawa balls for soup	Leaves are used as fodder
	Income generation	Falling leaves decay to improve organic matter of the soil
	Bark of tree for medicine	
	Cover of the fruits are and used to paint local houses	Soil cover
	Branches used as fuel wood for households	
Baobab	Leaves for preparing soup	The tree is fire resistant and can survive severe droughts,
	Seeds for oil and soup	
	Powder is eaten raw for making drinks and cakes	It is free from any serious pests and diseases
	Both seeds and powder at sold to earn income for households	It provides shade and protects the soil against erosion.
	The trunk provide shelter for animals all parts of the tree have medicinal properties	

boost soil organic matter. This finding is in agreement with both Duke (1983) and Wood (1992) that whitehorn tree is the only tree with this special feature of shedding leaves in the rainy season. Farmers said, *"We record the highest crop production on fields where whitethorn species are found"*. Table 5 indicates farmers rating of the benefits of the trees. Farmers derive a lot of incentives from agroforestry such as generation of income mentioned by 93% (70 of 75). The rest are ecosystem service such as shade reported by 65% (49 of 75) and ecosystem goods like constructional material indicated by 48% (36 of 75), fuel wood specified by 43% (32 of 75) and medicinal products stated by 39% (29 of 75).

The types of agroforestry practices include home garden (49% males and 48% females), woodlot (21% males and 14% females), trees on farm lands (30% males and 33% females) and plantation/crop combination (15% male and 29% females). Management practices are watering of trees (97%), fencing (83%), manuring (43%), mulching (35%), weeds removal (32%), making fire belt (27%) and applying bones/flour (16%). In a focus group discussion at Nakong it came out that:

The success of agroforestry depends largely on tree management practices. Farmers noted that tree management practices make trees on farm lands bear more fruits than those in the wild and also reduce the effects of bush fires on trees.

In addition, a key informant from the District Office of Ministry of Food and Agriculture (MoFA) has this to say:

"The survival of the trees seedlings depends on the seriousness with which farmers undertake tree management practices such as watering, fencing, construction of fire belts among others. For instance, some of the farmers do not use their donkey carts to water the trees regularly and as a result, survival rate is very low for such farmers".

Protecting tree seedlings through fencing is key to the survival of trees planted. This is carried out in three ways by using tree branches (43 of 75, 60%), young and undesirable trees (14 of 75, 19%) and barbed wire (25 of 75, 35%). Other practices adopted by farmers to manage agroforestry include spacing of crops and tree in a special way so as to reduce the impact of too much shade (55%, n = 75). Pruning (35%, n = 75)) and lopping (15%, n = 75) are usually done at the beginning of the farming season before planting the crops. Farmers grow shade tolerant or shade loving crops (13%, n = 75).

Any effective interaction of agroforestry components depends largely on farmers' actions. Farmers are responsible for providing

Table 5
Farmers Rating of the Benefits of the Trees.

			Ranking of the importance		
Agroforestry Benefits	Freq.	%	Least important	Important	Most important
Income	70	93	1	21	78
Shade	49	65	9	65	26
Construction material	36	48	29	50	21
Fuel wood	32	43	3	68	29
Medicine	29	39	19	52	29
Fodder	12	16	25	50	25

Table 6
Relationship between Agroforestry and the changing local climate (n = 75).

Impacts of Variable Local Climate	Contribution of Agroforestry as adaptation (farmers' perception)	Description
Drought	Access to fodder (20%) Trees are more resistant to drought (32%) Increase soil moisture (42%) Moderate microclimate (37%)	Trees are able to withstand drought for a longer period, increase moisture content of the soil and moderate microclimate which enhance the ability and capacity of farmers to adapt to the impacts of climate change
Floods	Reduce erosion (42%) Reduce runoff (15%)	Trees on farm reduce erosion which helps to retain the nutrients of the soil for food crop production.
Wind storms	Protect food crops (41%) Protect houses (38%) Reduce wind erosion (45%)	Farmers reported that agroforestry protects crops and houses from the destruction by wind storms. It also makes it difficult for the topsoil particles to be blown away by the storms.
Food insecurity	Increase food crop production (42%), increase access of income (55%), Source of food for households (58%)	Agroforestry is a good strategy that promotes food security because it enriches nutrients of the soil and improves food crop production, generates income for households through the sale of tree products, the fruits are source of food.
Soil infertility	Improve soil nutrients (62%) Provide soil cover (47%)	Agroforestry practices rehabilitate degraded soils by adding vital nutrients to the soil and also provide soil cover that helps in retaining soil moisture.

animals' shelter and ensuring that the animals are well fed. Pens and kraals are constructed using tree branches and soil. Crop residue is used by livestock as feed. By so doing, farmers cater for trees, crops and animals in the agroforestry.

4.3. Farmers' perspective on agroforestry as an adaptation to the changing local climate

Table 6 shows farmers opinions on the relationship between agroforestry and the local variability in climate. A farmer at Sakaa had this to say "*I know we do not receive adequate rainfall in northern Ghana as compared to the south because the south have more trees*". About half of the farmers (52%) associates variability in rainfall in northern Ghana to harvesting of trees for various purposes. In drought period, trees are more resistance than crops and supply animal feed, soil moisture and shade. During the 2007 floods, agroforestry farmers reported of minimal damage as the roots and stems of the trees reduced the speed of the floods, blocked and maintained soil particles and other eroded material.

4.4. Assessment of challenges in agroforestry

Agroforestry is difficult and requires attention of the farmer. Table 7 displays the challenges and their adaptation measures. Water scarcity is a major challenge. All the water sources are adversely affected by erratic and inadequate rainfall as reported by 97% of the farmers. Farmers trek long distances with water containers and donkey carts to fetch water from ponds. Some create their own wells with simple tools. Both crops and tree seedlings are often attacked by livestock during unsupervised grazing. "*Agroforestry practice is time consuming especially in the initial stages. I have to visit the farm daily to prevent livestock from destroying the trees and also to water the trees*" (a farmer at Kajelo).

5. Conclusion and recommendations

With regards to the first study objective, farmers' perception on a changing local climate is confirmed on two counts; by rainfall and temperature data from synoptic weather station as well as from the literature. There are decreasing rainfall and rising temperature trends which agree with national trends as reported in Ghana's climate change analysis (USAID, 2011; UNDP, 2018). Majority of farmers associates changes in windstorm, recurrent drought and floods to global climate change. The IPCC confirms unprecedented alteration in the global climate during the 20th century with attendant global impacts. The warming Earth and rising temperature globally are consistent with farmers' perception on increasing sunshine and temperature in their local climate (IPCC, 2007). Both the Ministry of Food and Agriculture and NGOs should factor the changing climate trends into climate-smart cropping systems.

Table 7
Challenges and their Adaptation Measure.

Challenges	Effects on tree growing	Adaptation strategies
Scarcity of water (95%)	Difficulty in tree survival	Use hand dug wells (69%) and covers long distance to get water (24%)
Livestock grazing (65%)	Animals destroy trees	Fence trees (61%)
Termites affect survival of seedlings (44%)	Reduces number of trees	Use bones/flour to attract *camponotus* which attacks and eliminates termites (fire ants are known to prey on termites in the Brazilian Amazon)
Perennial bushfires (35%)	Burn seedlings	Construct fire belt
Unfavourable land tenure arrangement	Reduce women participation in agroforestry	Women support their husbands

The second objective looked at agroforestry practices. In this regard, maize stood out as the dominant crop planted under various trees. Home garden is the preferable practice. It is fenced with various materials of which barb wire is the common material. Farmers are more concern about the shade of trees as it may affect crop growth and development. Home gardens become particularly important under increased population resulting in land fragmentation (Nair, 1993). It provides agroforestry purposes such as access to food and sale of food and other products to generate income. Hence, provision of fencing materials by government and NGOs could be a boost to farmers' efforts. Also, farmers should be involved in evolving climate-smart agricultural adaptation.

Objective three focused on agroforestry as adaptation to the changing local climate. In the rainy season agroforestry prevents soil erosion and improves soil nutrients. In the dry season it prevents wind erosion and enhances soil moisture retention. In all the season, it provides food and income for the households. Agroforestry holds the potential to help farmers adapt to the impacts of the changing local climate. In line with the conceptual framework, agroforestry is used to counter the impacts of variable climate (Ozor et al., 2012). Agroforestry helps to reduce weed re-growth and reduces incidence of pest and disease. Crops in agroforestry fare better under drought conditions. Agroforestry ensures tree vegetation and crop cover for the land. Hence, the government and NGOs should encourage more farmers to adopt it.

The fourth objective assessed challenges in agroforestry practice. The main challenges are water shortages, unsupervised livestock grazing, termites' infestation and perennial bushfires. These challenges are possible factors which could reduce the benefits of agroforestry. Therefore, the success depends on farmers resolve to protect their investments in agroforestry. Farmers' attempts to supply water, eliminate termites and create fire belts around agroforestry are findings that make good the gaps in the literature. Agidie et al. (2013) and Tom-Dery et al. (2014) found various challenges of agroforestry as climate change adaptation but failed to provide solutions. In the long term, government policy on the provision of dams for rural communities may reduce the water problem. The District Assembly should put measures in place to ensure supervised livestock grazing. NGOs could experiment the use of ants (*Componotus*) against termites and disseminate the success stories.

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